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B70 11012

SUBJECT: Photography of Luna 16 on an Apollo Mission - Case 340

DATE: November 3, 1970

FROM: W. L. Piotrowski

ABSTRACT

Photography of the landing stage (or landing site) of Luna 16 from the CM on Apollo 14 and by the SM Cameras on Apollo 15 is investigated. Identification of the Luna 16 descent stage in photographs of the site (0°41'S, 56°18'E) taken with the Lunar Topographic Camera (LTC) on Apollo 14 (January 31 launch) will not be likely. At the distance of closest approach, the resolution of the LTC (∿16 m) is about 25 times lower than that necessary for identification of Luna 16. In fact, on Apollo 14 the resolution obtainable with the LTC is not sufficient to permit identification of the landing point of any soft-landed lunar spacecraft. However, West Crater (adjacent to the Apollo 11 landing site), the Surveyor 3 crater, and the impact craters caused by the Apollo 13 and proposed Apollo 14 S-IVB impacts could be identified in LTC photographs of the respective areas.

The Luna 16 site will appear in stereo photographs (∿1 m resolution) taken with the Panoramic Camera on Apollo 15. However, the high sun angles in these photographs (>65°) coupled with the relatively small size of the spacecraft will make identification of the Luna 16 descent stage highly unlikely. The Luna 15 impact crater may be large enough to be identified in the Apollo 15 photographs.

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MEMORANDUM FOR FILE

I. INTRODUCTION

Photography with CSM cameras on Apollo 14 and/or Apollo 15 of soft-landed lunar spacecraft, particularly Luna 16, and craters created by the impact of the Saturn IVB and the LM Ascent Stage is presently under consideration. In this memorandum the feasibility of photographing these features with the cameras on-board Apollo 14 and 15 is considered from the point-of-view of location and photographic resolution. The operational problems inherent with these tasks on Apollo 14 (such as orienting the CSM) are not considered.

II. TARGETS

The location of the successful soft-landing lunar spacecraft - Surveyors, Lunas, and the Apollo LM descent stages, - are shown in Figure 1, along with the impact points of impacting lunar spacecraft - the Rangers, the Lunas, the Apollo LM/AS, and the S-IVB. Also shown in this figure are the illuminated terminator-to-terminator ground tracks for Apollo 14 (for a January 31, 1970 launch) and the extent of the rectified Panoramic Camera coverage of Apollo 15.

Table I lists the approximate size of the targets and the photographic resolution required for target identification. The identification criterion used was that, in the absence of other data, 3-4 resolution elements are required for positive visual identification from a photograph taken at moderate sun angles ($\sim 40°$). Application of this criterion means that a resolution of better than 0.5 m is required for identification of Luna 16, 1.0 m for landed Surveyors, 1.5 m for LM descent stages, 2.1 m for Ranger impact craters, and 15 m for S-IVB impact craters.

The identification criterion implies that slightly less resolution and higher sun angles can be tolerated if the shape and dimensions of the target are known and the photograph

is scanned electronically. In fact, the landing point of Surveyor 1 was determined by electronic scanning of a Lunar Orbiter 3 picture taken at a surface resolution of 1.14 m and at a sun angle of 71°.*

III. PHOTOGRAPHIC OPPORTUNITIES

A) Apollo 14

The Apollo 14 photographic complement will include the Lunar Topographic Camera (LTC) which has a resolution of approximately 5 m from a CSM altitude of 110 km and a resolution of about 1 m from an altitude of 15 km. Photography from the CSM is feasible on either the low orbit passes (revolutions 4-12) when the spacecraft is in a 110 x 15 km orbit or on the high orbit passes (revolutions 13-32) when the orbit is 110 km circular. Table II shows the distance of closest approach of the CSM to the targets, the corresponding sun angle at the target, the corresponding resolution of the LTC, and the resolution required for identification.

Based on these data it can be concluded that on Apollo 14:

1) no landed spacecraft (i.e., Luna 16, Surveyors, or LM descent stages) would be identifiable in any photography taken with the LTC,

2) the craters formed by the impact of the S-IVB (both Apollo 13 and Apollo 14) could be located in LTC photographs of the appropriate area, and

3) the crater formed by the impact of the Apollo 12 LM ascent stage, by Rangers, or by Luna 5 could not be identified in LTC photographs.

Although neither the Apollo 12 LM descent stage nor the Surveyor 3 spacecraft would be identifiable, the 200 m crater adjacent to the Apollo 12 landing point (the one in which Surveyor 3 landed) would be visible in photographs of this area. West Crater, adjacent to the Apollo 11 landing point, could also be identified in photographs taken with the LTC of the appropriate area.

B) Apollo 15

Figure 1 shows the greatest possible extent of the Panoramic Camera coverage (stereo coverage at 1 m resolution) on Apollo 15, assuming SIM door jettison post-LM landing and

*Surveyor Program Results, NASA SP-184, 1969.

parallel orbital science/surface activities. The only targets within this coverage are the Luna 15 impact crater, the Luna 16 landing site, and, of course, the Apollo 15 LM.*

The Luna 16 site will be overflown on rev 61 and the area will be in all nominal rectified pan camera photographs taken at the appropriate times between revs 54 and 68. Table III lists the sun angle at the site, the length of the shadow cast by Luna 16, and the resolution of the rectified photographs at the site as a function of the rev number. Note that on a 13-day mission the last photographic pass occurs on rev 57, while on a 14-day duration mission the last photographic pass of interest is rev 68. From Table III it can be seen that identification of the Luna 16 landing point is unlikely in any Panoramic Camera photographs taken on Apollo 15 due to the relatively small size of the spacecraft ($\leq$2 m square), the high sun angle at the Luna 16 site at the time of photography (>65° even on a 14-day mission) and the resolution of the photography (1 m stereo).

If the Luna 15 impact crater is greater than 4 m in diameter (implying a high velocity impact), the resolution of the panoramic photography will be sufficient for identification since the CSM overflies the site on revolution 26. The Luna 15 impact site will appear in all nominal rectified panoramic photographs (i.e., SIM bay oriented toward the lunar surface) taken at the appropriate time between revolutions 19 and 33 with the sun angle at the site between 66 and 80°.

IV. SUMMARY

Identification of the landing site of any soft-landed lunar spacecraft (including the five Surveyors, the LM descent stages, and Luna 9, 13, and 16) is not feasible from the photographs taken with the LTC on Apollo 14 (assuming a January 31, 1970 launch). However, the S-IVB impact craters (both Apollo 13 and the proposed Apollo 14) could be located in photographs of the appropriate region taken with the LTC. In addition, West Crater (adjacent to the Apollo 11 landing point) and the crater in which Surveyor 3 landed could be identified in photographs of the respective areas taken with the LTC.

*Additional man-made targets are not overflown on Apollo 15 by earlier jettisoning of the SIM door (either pre-LOI or pre-DOI) nor by extension of the mission duration to 14 days.

The Luna 16 landing site and the site of the Luna 15 impact will be overflown on Apollo 15 and stereo photographs of these areas (∿1 m resolution) will be taken with the Panoramic Camera. However, identification of the Luna 16 spacecraft in the photographs is unlikely due to the relatively small size of the spacecraft (≤2 m square), the high sun angles at the site at the time of the photography (>65°) and the photographic resolution (1 m).

The Luna 15 impact crater could be located in the photographs only if the spacecraft impacted at a high velocity forming a crater >4 m in diameter.

W. L. Piotrowski

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Attachments
Tables I-III
Figure 1

TABLE I

LOCATION OF POSSIBLE MAN-MADE PHOTOGRAPHIC TARGETS-OF-OPPORTUNITY FOR APOLLO 14 AND APOLLO 15

A) SOFT-LANDED SPACECRAFT

	Landing Coordinates	Spacecraft Size	Photographic Resolution Required for Identification
Surveyor 1	-2.46°, -43.23°	3 m triangular base 2.9 m high	1.0 m
Surveyor 3	-2.94°, -23.34°		
Surveyor 5	1.45°, 23.25°		
Surveyor 6	0.51°, -1.39°		
Surveyor 7	-40.88°, -11.45°		
Apollo 11 LM/DS	0.66°, 23.48°	6 m square base 3.1 m high	1.5 m
Apollo 12 LM/DS	-2.94°, -23.34°		
Apollo 14 LM/DS (targeted)	-3.67°, -17.65°		
Luna 9	7.6°, -64.2°	∿1.5 m square base (unfolded) .7 m high	0.4 m
Luna 13	18.8°, -62.0°		
Luna 16	-.685°, 56.30°	2 m square base 1.75 m high	0.5 m

TABLE I (CONT'D.)

B) IMPACTING SPACECRAFT

	Landing Location	Crater Size diameter	Crater Size depth	Resolution Required for Identification
Ranger 6	9.44°, 21.50°	8.4 m	2.1 m	2.1 m
Ranger 7	-10.70°, -20.67°			
Ranger 8	2.71°, 24.81°			
Ranger 9	-12.82°, -2.33°			
Luna 2	31°, 0.4°	8.4 m	2.1 m	2.1 m
Apollo 12 LM/AS	-3.95°, 21.07°	4 m	0.2 m	1.0 m
Apollo 13 S-IVB	-2.4°, -27.4°	60 m	15 m	15 m
Apollo 14 S-IVB	-1.72°, -33.25°			
Surveyor 4*	0.37°, -1.55°			
Luna 5**	-2°, -25°			<1.0 m
Luna 8**	9.2°, -63.3°			
Luna 15**	15°, 58°			

*result of soft-landing attempt unknown, radio contact lost 2 1/2 min prior to landing

**unsuccessful soft-landing, crashed on moon, size of craters unknown

TABLE II

APOLLO 14 PHOTOGRAPHY OF MAN-MADE LUNAR TARGETS

TARGET	DISTANCE OF CLOSEST APPROACH				
	rev no.	sun angle at site	slant range	LTC resolution at this range	Resolution Required for Identification
Surveyor 1	32	8°	160 km	7.5 m	1.0 m
Surveyor 3	32	22°	120 km	5 m	
Surveyor 5	4	40°	320 km	14 m	
Surveyor 6	4	16°	180 km	8 m	
Surveyor 7	beyond visible horison				
Apollo 11 LM/DS	4	40°	320 km	14 m	1.5 m
Apollo 12 LM/DS	32	22°	120 km	5 m	
Apollo 14 LM/DS	32	28°	110 km	5 m	
Luna 9	beyond sunrise terminator				
Luna 13	beyond sunrise terminator				
Luna 16	26-32	84°-78°	347 km	16 m	0.5 m

TABLE II (CONT'D.)

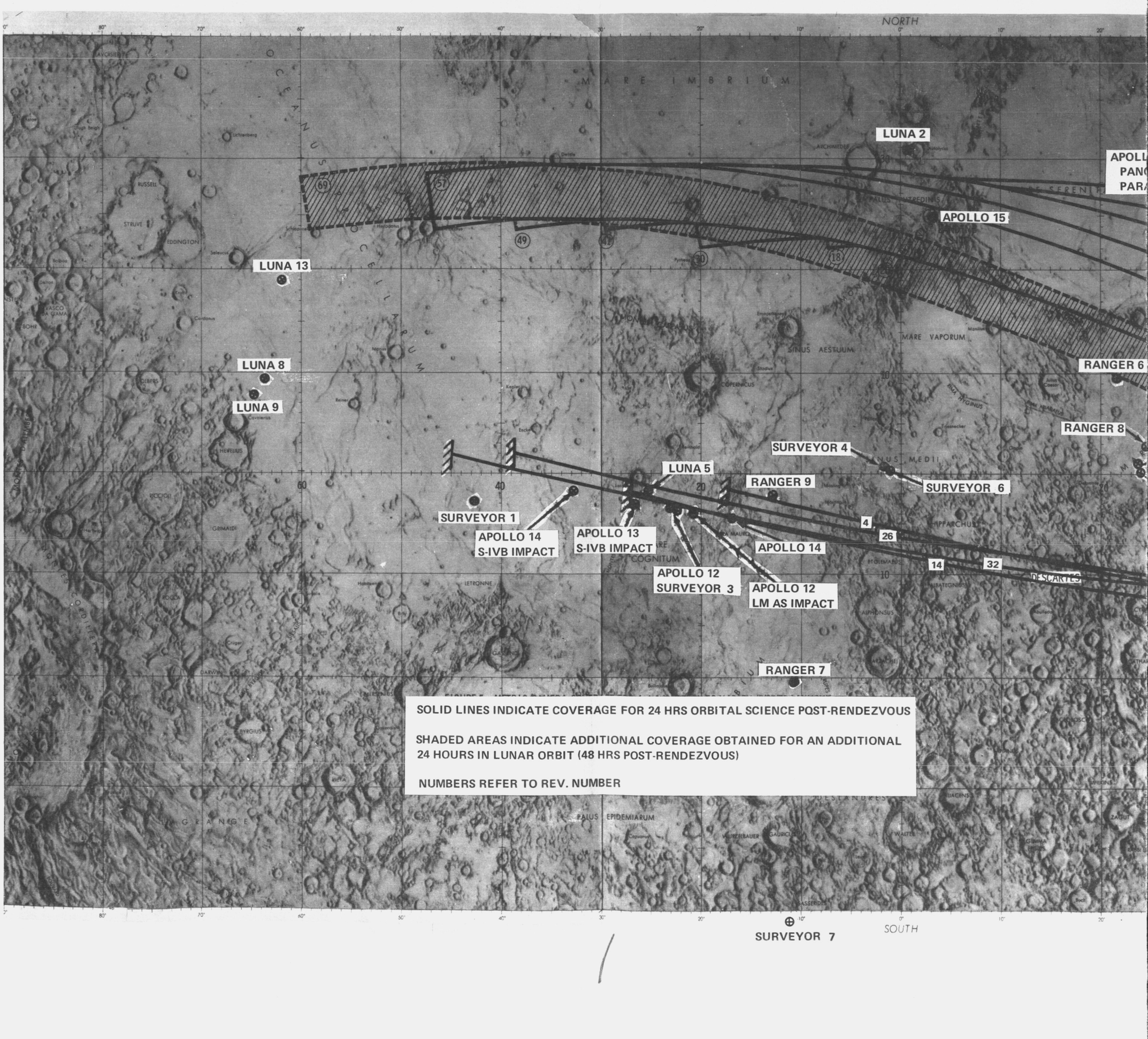
TARGET	DISTANCE OF CLOSEST APPROACH rev no.	sun angle at site	slant range	LTC resolution at this range	Resolution Required for Identification
Surveyor 4 Impact	4	16°	180 km	8 m	≤1.0 m
Ranger 6 Impact	26	60°	600 km	28 m	2.1 m
Ranger 7 Impact	32	25°	240 km	11 m	
Ranger 8 Impact	4	4°	340 km	15 m	
Ranger 9 Impact	10	31°	140 km	7 m	
Luna 2 Impact	beyond visible horizon				
Luna 5 Impact	26	14°	115 km	5 m	<1.0 m
Luna 8 Impact	beyond sunrise terminator				
Luna 15 Impact	beyond visible horizon				
Apollo 12 LM/AS Impact	32	25°	120 km	5 m	1.0 m
	10	3°	70 km	2.5 m	
Apollo 13 S-IVB Impact	32	18°	120 km	5 m	15 m
Apollo 14 S-IVB Impact	32	12°	120 km	5 m	

TABLE III

PHOTOGRAPHY OF LUNA 16 ON APOLLO 15

REV. NO.	SUN ANGLE AT LUNA 16	LENGTH OF LUNA 16 SHADOW*	RESOLUTION IN PAN PHOTOS AT LUNA 16 SITE	RESOLUTION REQUIRED FOR IDENTIFICATION
54	79°	.34 m	1.4 m	0.5 m
57	76°	.44 m	1.1 m	
61	72°	.58 m	1.0 m	
65	68°	.71 m	1.1 m	
68	65°	.86 m	1.4 m	

*Assumes no slope.


NORTH
SOUTH
LUNA 2
APOLLO 15
LUNA 13
LUNA 8
LUNA 9
RANGER 6
RANGER 8
SURVEYOR 4
LUNA 5
RANGER 9
SURVEYOR 6
SURVEYOR 1
APOLLO 14
S-IVB IMPACT
APOLLO 13
S-IVB IMPACT
APOLLO 14
APOLLO 12
SURVEYOR 3
APOLLO 12
LM AS IMPACT
RANGER 7
SURVEYOR 7
SOLID LINES INDICATE COVERAGE FOR 24 HRS ORBITAL SCIENCE POST-RENDEZVOUS
SHADED AREAS INDICATE ADDITIONAL COVERAGE OBTAINED FOR AN ADDITIONAL 24 HOURS IN LUNAR ORBIT (48 HRS POST-RENDEZVOUS)
NUMBERS REFER TO REV. NUMBER
OCEANUS PROCELLARUM
MARE IMBRIUM
MARE VAPORUM
SINUS AESTUUM
MARE COGNITUM
PALUS EPIDEMIARUM
RUSSELL
STRUVE
EDDINGTON
VASCO DA GAMA
BOHR
CARDANUS
KEPLER
COPERNICUS
ARCHIMEDES
HERODOTUS
SCHRÖDINGER
PYTHEAS
HEVELIUS
GRIMALDI
LETRONNE
DARWIN
BYRGIUS
HIPPARCHUS
PTOLEMAEUS
ALPHONSUS
DESCARTES
APOLLO 15
PANO
PARA
4
26
14
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69
57
49
41
30
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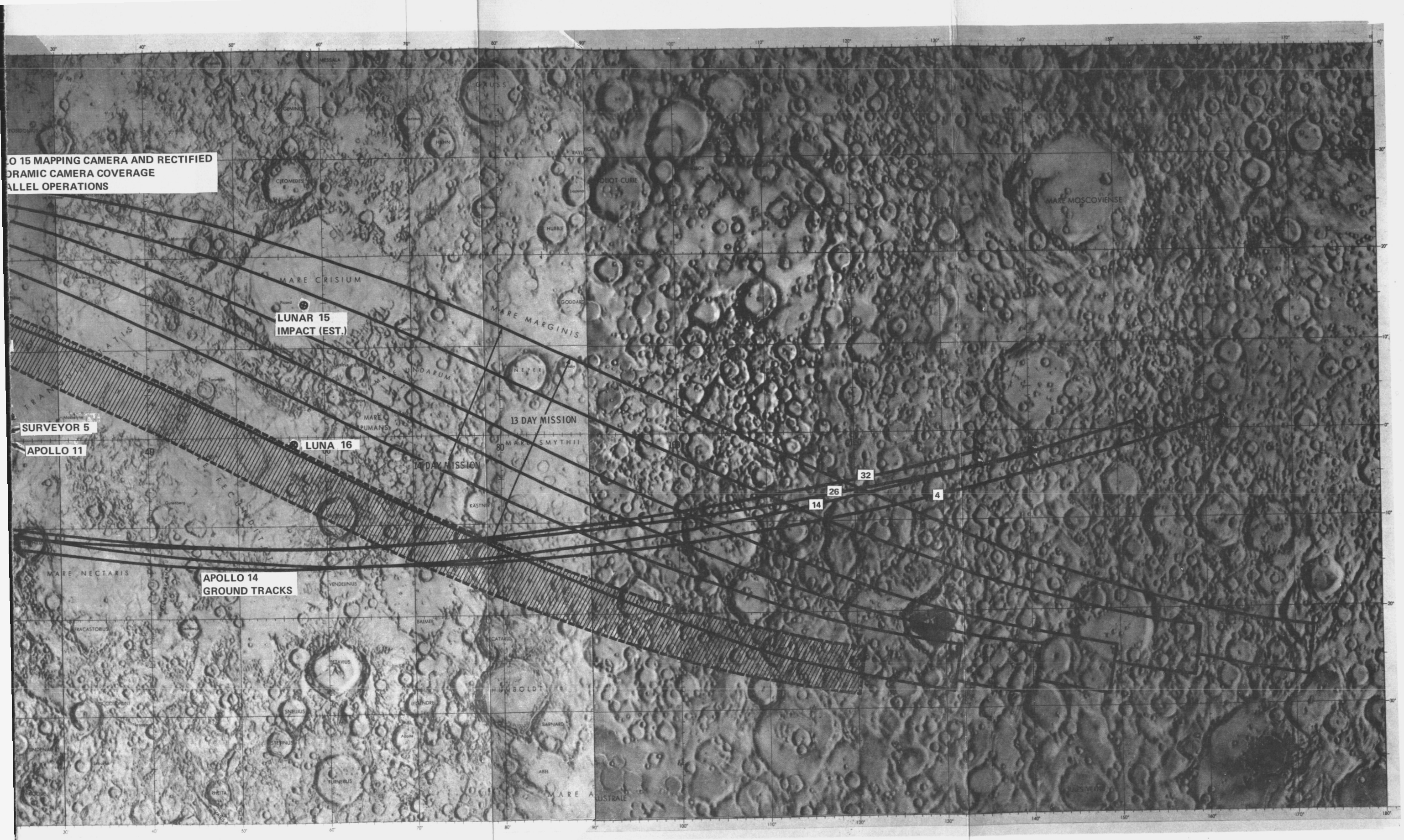
LO 15 MAPPING CAMERA AND RECTIFIED
DRAMIC CAMERA COVERAGE
ALLEL OPERATIONS
LUNAR 15
IMPACT (EST.)
SURVEYOR 5
APOLLO 11
LUNA 16
13 DAY MISSION
14 DAY MISSION
APOLLO 14
GROUND TRACKS
32
26
14
4
MARE CRISIUM
MARE MARGINIS
MARE NECTARIS
MARE MOSCOVIENSE
GAUSS
HUBBLE
GODDARD
COLIOT CURIE
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FIGURE 1

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FROM: W. L. Piotrowski

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